was found in a collection of minerals where it had attracted no attention until Mr. Spang obtained the specimen and brought it to the notice of Mr. Penfield; the present specimen has probably remained unnoticed in the Cornish collection at Caerhays for a large number of years.

The local collection from which the American specimen was obtained belonged to a man living near Tombstone, Arizona, who had gathered together his minerals within a radius of about two hundred miles, so that although the exact locality and mode of occurrence are unknown, it is almost impossible that this specimen can be also Cornish.

From the typical character and appearance of the associated clinoclase and liroconite the British Museum specimen (although no label or history is attached to it) can be pronounced to be without the least doubt from the St. Day district, near Redruth, in Cornwall.

The American specimen is described as "a rounded mass of impure cuprite which was mostly covered with hexagonal crystals of spangolite, associated with a few crystals of azurite and some slender prismatic crystals of a copper mineral containing chlorine, probably atacamite"; it therefore differs considerably from the Cornish specimen as regards the associated minerals.

The only apparent difference between the spangolite on the two specimens is in the habit of the crystals, which in the American mineral are short prisms with bevilled edges and a large base, quite unlike the acute Cornish pyramids in aspect. The pyramid angle found by Penfield is 53° 11½′, and the specific gravity 3·141. Penfield further made some interesting observations concerning the etched figures of spangolite; he describes and figures certain beautiful triangular markings produced upon the basal plane by the solvent action of very dilute acids. We have found that precisely the same characteristic figures are engraved upon a cleavage flake of the Cornish mineral when it is immersed for a few minutes in dilute acid.

The American crystals attain considerable dimensions; the largest had a length of 5½ mm. and a breadth of 8 mm, and by sacrificing half the specimen Penfield was able to obtain more than 3 grams (!) of pure material for analysis. The Cornish crystals are not more than 2½ mm. in length and ¾ mm. in breadth, and it will be difficult to obtain sufficient material for a complete analysis, unless other specimens can be found. This is unfortunate, for the composition is so peculiar that, although Penfield's analysis is without doubt perfectly reliable, it would have been interesting to confirm his formula from a new locality. The preliminary examination serves, however, not only to establish the identity of the mineral, but also to prove the most important point—that the aluminium and chlorine are essential constituents.

The formula deduced by Penfield is

$$Cu_6AlClSO_{10}\cdot 9H_2O.$$

in which, as he remarks, the aluminium is just sufficient to satisfy the quantivalence of the total acids, thus:—

$$(AlCl)SO_4.6Cu(HO)_2\cdot 3H_2O.$$

The mineral is therefore closely related to connellite, a very rare sulphate and chloride of copper also found in the St. Day district, which, moreover, it somewhat resembles in appearance, having the same black colour when viewed by reflected light alone. The colour by transmitted light, together with the perfect basal cleavage are, however, sufficient to distinguish spangolite from all known minerals; further, the basal plane is as common on spangolite as it is rare on connellite.

It is to be hoped that search will be made among old collections and upon copper ores from St. Day for further specimens of this interesting mineral. H. A. MIERS.

DESULPHURISATION OF IRON.

THE elimination of sulphur from iron and the chemical reactions, whereby sulphur, in the presence of powerful basic materials, is removed from crude iron, has recently attracted considerable attention. There are many reasons for this; pure ores have become comparatively scarce, and to some extent the same may be said of the fuel or coke used in the process of smelting. And even if this be not strictly applicable in all districts where the manufacture of iron is pursued, yet it cannot be gainsaid that excessive competition, with concurrent low prices, have had an influence in rendering the strictest economy in the manufacture absolutely necessary, and thus in a measure preventing the free use of pure high-priced materials.

I may even go further and assert that under favourable conditions, that is, as regards general manufacturing expenses, localisation of plant, &c., the cost of pure good materials, unquestionably suitable for smelting purposes, may become quite prohibitive. In numerous instances manufacturers have therefore been compelled to use cheaper fuel and ores falling within the margin of economic working. At this point, however, other fresh difficulties have to be combated; for when the problem of the production of iron and steel at a reasonable rate has been solved, it is too often found that the metal thus manufactured fails to meet demanded requirements. It is often the case that when iron thus produced is converted into steel, a want of uniformity in quality can be distinctly traced throughout the manufactured product. Though the steel can hardly be termed bad, nevertheless, as a general rule, it compares unfavourably with the metal smelted from purer ores with good fuel or coke.

The causes tending to the production of this inferior metal or steel are well known, and may be summed up in a few words. (1) The use of inferior coke in the blast furnace is at once a cause of deterioration, for the heat is less intense, and this tends to the production of a low grade iron.

(2) It is evident that the use of inferior cheaper ore causes a further deterioration in quality, whilst any attempt to remedy this by lightening the furnace burden of ore—in other words, using a greater quantity of coke—is, in many instances, counterbalanced by the inevitable additional impurities charged, *i.e.* sulphur and phosphorus, and other additional incombustible matter or ash.

It follows as a matter of course that the blast furnace can only work in this direction within a very narrow limit, either plus or minus attempts to limit the quantity of coke used resulting, as before said, in the production of low grade iron. On the other hand, an increased quantity of fuel with the use of inferior ore increases the total amount of impurities.

The working limit on either side is soon reached, and any further attempts at improvement either way become simply useless. Certainly, very highly heated air or blast might to some extent obviate some of the difficulties, but as in modern practice this is already thoroughly carried out, the employment of a higher temperature of blast would appear to be practically impossible, and it is very likely that the attempted use of abnormally heated blast or air would entail other serious practical difficulties.

This is the common experience of those engaged in the manufacture of iron and steel, more especially in blast furnace smelting operations, showing that under the unfavourable conditions before mentioned, it is practically impossible to produce a high-class iron containing the minimum percentage of sulphur and phosphorus together, with the requisite quantities of silicon and graphite necessary to ensure the production of good steel.

Thanks to the pain taking investigations of Mr. Stead, we can now form a tolerably clear idea of the reactions involved in the elimination of sulphur, both in the blast furnace and by other or secondary processes. These may be broadly summed up in his statement that sulphide of iron is dissolved out of the metal in the first instance by free or loosely attached lime, in a highly reducing atmosphere at a high temperature, as by the Saniter process, where lime dissolved in calcium chloride is used; and in the blast furnace by the excess of lime in solution in the slag, or even a mixture of ordinary blast furnace slag and lime, the latter being capable of eliminating sulphur from iron, and may be substituted for Saniter's mixture. The results, however, so far as can be ascertained, are somewhat irregular with either of these methods. Finally, there can be little doubt, as suggested by Mr. Stead, that if lime alone is brought into intimate contact with molten iron by suitable mechanical appliances, neither calcium chloride nor slag is needed, these having little or no direct chemical action on the metal, but merely forming vehicles for the transmission and mixing of the lime with the iron, and consequent washing out of solution of iron sulphide, followed by the subsequent conversion into calcium sulphide and iron oxide.

"The reactions in this process are, however, exceedingly complex, and there are changes which occur of which we know little or nothing. It is, however, my opinion that the sulphide of iron is dissolved out of the metal in the first instance by the free or loosely-attached dissolved lime; but I do not care at present, without more extended investigations, to hazard an

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opinion as to what the subsequent reactions may be."[1] Subject to what may be said of particular instances or occasional exceptions, the statements made by me as to the result of many years' observation and experiment of others and myself are on the whole practically accepted. Probably Mr. Stead is correct when he assumes that the dissolved iron sulphide is resolved into calcium sulphide, and iron oxide, as by the Saniter process, or in the blast furnace, by the excess of lime in solution in the slag.

In this connection, as regards the blast furnace, heat plays a double part, firstly for the intensification of the chemical affinity of sulphur for the alkaline base (lime, of the slag; secondly, for the adequate liquefaction of this highly basic slag, overcharged with lime and requiring a high temperature for its perfect fusion, which otherwise would remain in and clog up the blast furnace, thus obviously checking the proper working of the furnace and the uniform descent of the materials charged above.

Phosphorus is apparently not eliminated in sensible quantities under the above conditions. Practically the whole is retained and passes into the pig iron. Blast furnace slags are, however, never quite free from phosphorus, and some species of the latter contain sensible quantities, the amount depending on the excess of phosphorus present in the ores, and the working conditions. Usually such slags contain an excess of iron oxide as compared with ordinary grey iron slags, the latter being generally free from iron oxide or, at any rate, the amount does not exceed ½ per cent. in good slag.

Metallurgical experts have for some time been engaged in devising methods for the removal of sulphur. It is needless here to recapitulate in detail the very many processes tried by them, and for the most part abandoned. All are based on the use, in one way or another, of alkaline or basic materials. However, the experience thus acquired seems to have been utilised, and has led to valuable tangible results, for of late several processes have been worked out with some degree of success, but in our opinion there is still room for improvements, both in cost and general efficiency. In addition, the time and trouble involved in these processes ("which may be classified as methods of secondary purification," *i.e.* methods by which the iron is to some extent freed from sulphur after its production in the blast furnace) are important items seriously impeding further progress. It really seems that the proposed methods of secondary purification may ultimately prove too tedious and expensive, the limit betwixt loss or gain being just now very small. Recognising this, attempts have been made to cheapen the processes, all, however, based on the use of alkaline or basic material, but so far it appears the results are somewhat uncertain.

Mr. Saniter's lime and calcium chloride method, "one of the first recently proposed and tried," has been worked, as the writer can testify, with some success, but the costs, by general consent, are considered somewhat heavy. It is only fair to say that the inventor is not of this opinion, and he quotes reasons to the contrary which should be well weighed before a final opinion is held as to the merits of this process. Secondary processes must from their very nature be costly and troublesome when dealing with the production of thousands of tons of metal continuously flowing from the blast furnace throughout the year.

The earlier attempts to purify crude iron from sulphur, &c., merely paved the way for recent developments, and, on the whole, merely suffice to prove that alkaline or basic substances only can effectively be used. It is now generally admitted that lime is the only base which can be applied with anything approaching economic results, and the methods now being practised have resolved themselves into endeavours to use this reagent efficiently and economically. Manganese as another reagent is an effective desulphuriser, but this requires to be separately investigated.

Lime is, and always has been, used in the blast furnace for the elimination of sulphur from iron; and it is well known that a non-sulphury pig-iron cannot be manufactured unless an excess of lime be charged into the furnace over and above the lime required for the formation of a fluid slag or lime silicate. It is evident, however, that the use is limited owing to the infusibility of the basic slags formed. These are facts which need no further comment, as they are universally acknowledged on all sides. If some modification could be introduced into ordinary blast furnace charging whereby this infusible slag containing an excess of lime could be continuously cleared out of the furnace, we should have at our command a continuous *direct* method of eliminating sulphur from iron at a minimum expenditure, and at a great saving in the time and labour involved in the processes of purification.

JOHN PARRY.

THE METEOROLOGICAL OBSERVATORY ON BEN NEVIS.

THE Directors of the Ben Nevis Meteorological Observatory have prepared a guide book which will be of great use to the tourist who desires to scale the top of the Ben and feast his eyes upon the crag and mist beneath, and also to the large number of people interested in meteorology. By the kindness of the publishers (Messrs. John Menzies and Co., Edinburgh and Glasgow) we are able to give three illustrations of the Observatory, with an account of its foundation and the work carried on there. For many years it has been recognised that the best means of obtaining definite information as to the vertical variation of atmospheric conditions was to establish meteorological stations differing considerably in altitude but in the same locality. In this connection we read that "in 1877 Mr. Milne Home, then Chairman of the Council of the Scottish Meteorological Society, pointed out the singular advantages of Ben Nevis as a high-level station. It is the highest mountain in the British Islands (4406 feet); its summit is, in horizontal distance, about four miles from a sea-level station at Fort William, and is situated in the track of the south-west storms from the Atlantic, which exercise such a preponderating influence on the weather of Europe, especially in autumn and winter. Its advantages are therefore unique, and observations made there have proved to be of the greatest interest and value to meteorology."

Unfortunately, though a plan of an observatory was prepared by the late Mr. Thomas Stevenson in 1879, for the Scottish Meteorological Society, the work could not be proceeded with for want of the necessary funds. From June to October, 1881, however, Mr. Clement L. Wragge made observations at the summit simultaneously with Mrs. Wragge at Fort William, and an elaborate series of simultaneous observations at different heights on the mountain were successfully made in the two following years. The discussion of these observations led to very important results, and was the means of exciting the interest in the public mind essential to the obtaining of subscriptions. An appeal for funds to enable an observing station to be erected was promptly responded to, a sum of £4,000 being soon collected. A feu of an acre of land was obtained on the top of the mountain from Mrs. Cameron Campbell, of Monzie, and upon it an observatory was erected from plans by Mr. Sydney Mitchell. "The observatory was opened by Mrs. Cameron Campbell on October 17, 1883. Observations were begun in the following month, and have been carried on ever since. At the same time a sea-level station was opened at the public school, Fort William, under charge of Mr. C. Livingston, where comparison readings were taken five times a day with great punctuality and accuracy. But a few years showed the necessity of having a continuous record at sea-level as well as on the summit, and in 1889 the directors resolved to carry out the original plan which want of funds had hitherto prevented, and set up a low-level observatory. Aided by a grant from the Edinburgh Exhibition of 1886 and contributions from the public, they were able to erect a suitable building close to sea-level, on ground feued from Mr. Cameron, of Lochiel, in the beginning of 1890. The Meteorological Council of London equipped this station with self-recording instruments, and increased their annual grant to the directors from £100 to £350. Observations began in the middle of July, 1890, and since then there has been a continuous record of barometric pressure, temperature, humidity, rainfall, &c., by day and by night, both on the summit of Ben Nevis and at sea-level. The distance between the high and low-level observatories is only 4¾ miles, and their heights above sea-level respectively 4407 and 42 feet. Mr. Livingston also continued his observations for a year after the commencement of the low-level observatory, so that there might be a satisfactory comparison of the two sea-level stations. The telegraph wire from the summit has been extended to the low-level observatory, and the observers can communicate with each other at any time, and reports from both stations are sent daily to the newspapers. The high and low-level stations are worked as one observatory, the observers being inter-

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[1] Stead, Iron and Steel Institute.

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